INSTRUCTION MANUAL

FOR

OPERATING AND MAINTENANCE

MODEL FS

TYPE D'ARSONVAL DOUBLE PIVOT

ACCURACY .5%

SCALE LENGTH 5.2"

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
NEW ROCHELLE, NEW YORK.

Symbol of Quality

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

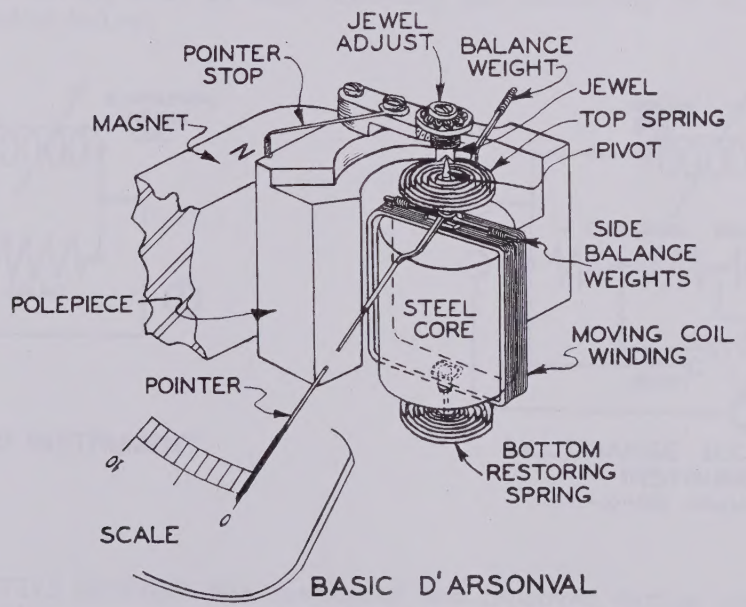
ELECTRICAL MEASURING INSTRUMENTS

D. C. CURRENT MEASUREMENTS

Almost all electrical measurements involve the detection or measurement of an electric current. An electric current can be measured by means of one or more of its physical effects;

1. Heating Effect
2. Chemical Effect
3. Magnetic Effect

Using the magnetic effect caused by a current flow, we can devise an accurate means of measurement. The oldest design of such a device is known as the D'Arsonval Moving Coil System. An elementary sketch of which is shown below.



BASIC D'ARSONVAL MOVING COIL ASSEMBLY

Its operation depends on the force exerted on a current carrying conductor shaped in a coil which is capable of rotation in the field of a permanent magnet.

When a D.C. current flows through this rotatable coil, it creates a field which interacts with the permanent magnet field and produces a torque.

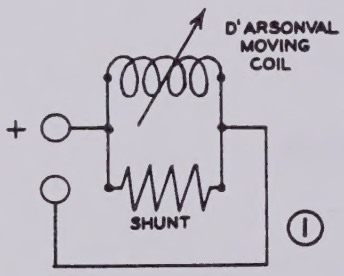
This torque is proportional to the magnet strength, the current in the moving coil, and the number and area of the moving coil turns. The torque produced rotates the moving coil until its spiral springs are wound up sufficiently to produce an equal and opposite torque. When this point is reached the pointer deflection will be directly proportional to the current which produced it.

Essentially, a D'Arsonval moving coil, which in Sensitive Research Instrument is reactangular in shape, has a steel or diamond pivot at each end which turns in spring mounted jewel bearings.

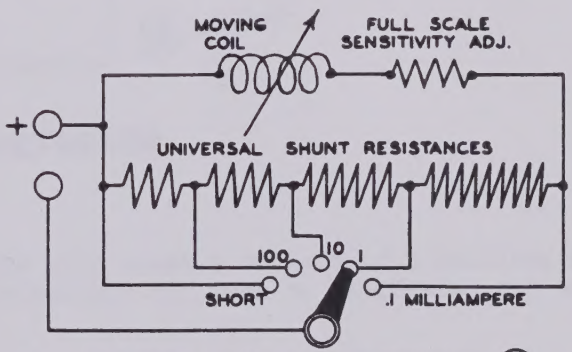
The D.C. current enters and leaves the moving coil usually through spirally constructed phosphor bronze springs which are coiled in opposite directions. These springs also provide the controlling force which opposes the deflecting force created by the current flow through the moving coil turns.

The accuracy of such an assembly to date is superior to any other known type of current deflected mechanism for electrical measuring instruments.

As such a moving coil system will not usually carry over 30 milliamperes without heating errors, we shunt any additional current past the moving coil. By means of calculated and accurately constructed shunts, either single or in a multiple system, we can measure D.C. currents of large magnitude even though the moving coil is only carrying and measuring 30 milliamperes or less. (See circuits below)



SHUNTED INSTRUMENT



MULTIRANGE D.C. CURRENT ② INSTRUMENT
.1-1-10-100 MILLIAMPERES

SENSITIVE RESEARCH has developed and improved during the past 31 years the basic D'Arsonval moving coil system so that today we use it even in our 1/20 of 1% LABORATORY STANDARD D.C. Instruments.

When properly constructed, a D'Arsonval moving coil system will accurately measure very minute D.C. currents as low as .01 of one microampere (.00000001 ampere) and indicate this small magnitude of current by a pointer on an indicating scale drawn in divisions-deflection. This extremely high sensitivity is unusual in portable indicating D.C. Instruments.

D. C. VOLTAGE MEASUREMENTS

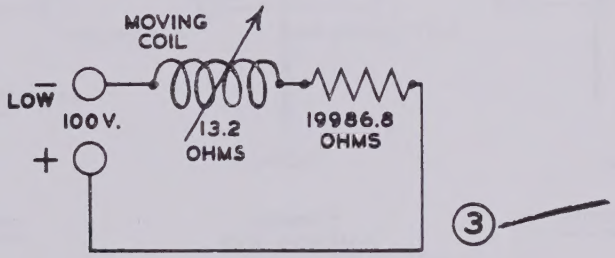
The D'Arsonval moving coil system movement is a current measuring device, but by following a principle of ohms law we can use this current measuring movement to measure D.C. voltage.

FOR EXAMPLE

Assume we wish to measure 100 volts direct current. Also assume that we have a D'Arsonval movement that deflects full scale for 5 milliamperes with a resistance of 13.2 ohms. By Ohms Law, 100 volts across a circuit of 20000 ohms will have a current flow of 5 milliamperes (.005 amperes) by:

$$\frac{100 \text{ Volts}}{.005} = 20000 \text{ Ohms}$$

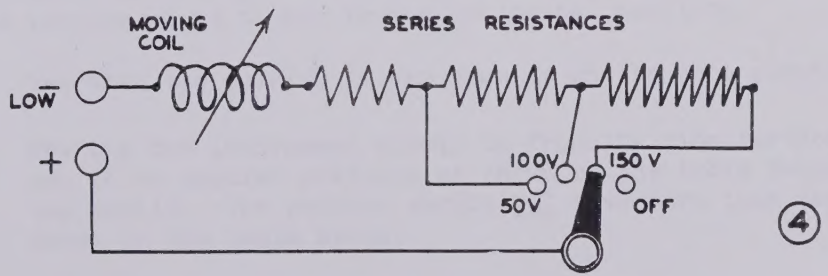
If we place our D'Arsonval moving coil (13.2 ohms) in series with a 19986.8 ohms resistor to equal 20000 ohms;



SIMPLE
SINGLE RANGE VOLTMETER
100 VOLTS

Then a potential of 100 D.C. volts will cause a current of 5 milliamperes (.005 ampere). Moving coil pointer deflection can then be calibrated and marked on the scale as 100 volts.

Using the ohms law formula and suitable calculated resistances, we can readily construct multirange D.C. Voltmeters.



MULTIRANGE D.C. VOLTMETER
50-100-150 VOLTS

GENERAL INFORMATION

Upon receipt, your instrument should be carefully unpacked and examined for any visible external damage, i.e; split case, cracked glass, broken binding posts, etc. Place the instrument on a reasonably level bench. If the instrument has a wire shunting (across) the terminals, it should be removed. With the mechanical zero adjuster thumb knob, move the pointer both above and below the zero line of the scale. It should have sufficient travel to go a little beyond zero in each direction. Set the pointer exactly on zero while lightly tapping the instrument case with your fingers. The pointer will be correctly adjusted for zero when no reflection of the pointer's knife edge can be seen in the anti-parrallax mirror and the pointer is directly over and in line with the scale zero.

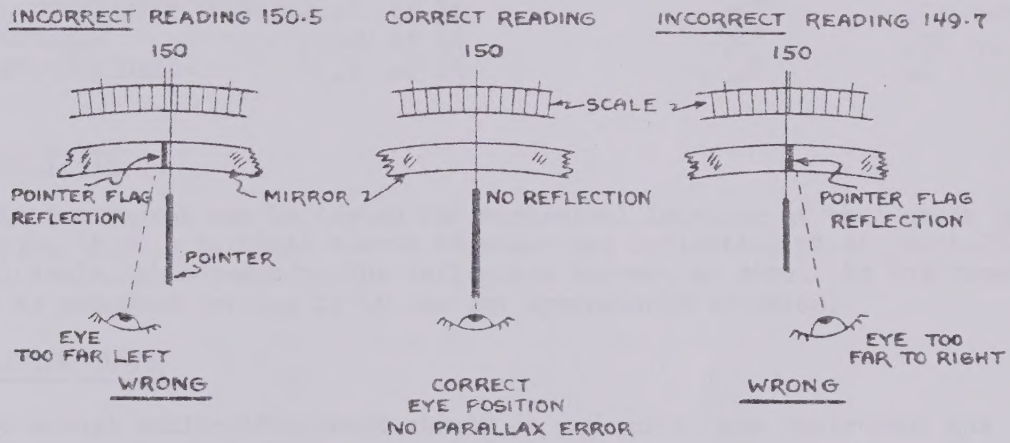


ILLUSTRATION OF THE ANTI-PARALLAX PRINCIPLE

The pointer indication should only be "read" when no reflection of its knife edge can be seen in the mirror below. This is only obtained when the eye is directly over the pointer. The drawings above illustrate the anti-parallax principle.

BALANCE TESTS FOR DIRECT CURRENT INSTRUMENTS

The general testing procedure for balance on all portable and panel instruments is the same, the difference being only in the degree of angle that the instrument is tipped from a horizontal position.

1. See that the pointer is set exactly on its zero position.

2. Now tip the instrument slowly up from the side farthest from you to an angular position as shown on the table below, and tap gently. The pointer should NOT move more than the amount shown on the table below.

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3. Next, lay the instrument flat again and then tip it on its side, first left, then right, and tap gently.

In both of these procedures, the instrument should be within its balance specifications. In general, these specifications are as follows:

DIRECT CURRENT INSTRUMENTS

MODEL	ACCURACY	ANGLE FROM HORIZONTAL	BALANCE GUARANTEE
UPP PANEL	.5 of 1%	90°	.5 of 1%
UP PANEL	1%	90°	.5 of 1%
J,JW,S, UNIVERSITY PORTABLE	.5 of 1%	25°	.5 of 1%
C PORTABLE	.25 of 1%	25°	.25 of 1%
B LAB. STANDARD	.1 of 1%	10°	.1

FRICTION TESTS

The instrument may be tested for mechanical friction at this point by connecting it to a suitable source of power and deflecting it at least 25% of full scale, then reducing the deflecting current to zero. No instrument should be accepted for use if it has any appreciable friction.

CALIBRATION CHECK

No actual calibration check should be made until the instrument has become thoroughly temperature saturated at ambient room temperatures for at least four hours. Allow it to reach room temperature. SENSITIVE RESEARCH calibrates all instruments at exactly 25° C.

Make sure you are on the right range for your power supply. If in doubt set the range switch, if any, on the instrument on its highest range. This will prevent overloading of the instrument when starting any electrical tests. If only a slight pointer deflection results when power is applied, then successively switch the instrument range selector DOWN until a suitable reading is obtained. Bring the pointer up to full scale and open the instrument circuit. A special precaution should be taken by the user of thermocouple instruments: AVOID opening the primary circuit of a transformer whose secondary circuit is being measured by thermocouple instruments. The reason for this is that the transformer as an energy storing device may, under certain conditions, DISCHARGE its energy into the secondary circuit, thereby overloading the thermocouple instrument. (Overloads of 1000% are quite possible in transformer circuits.)

This danger can be eliminated by either disconnecting the instrument from the secondary circuit which can be turned to "zero" so that the excitation of any transformer primary may be reduced to "zero" before switching off.

The pointer should return to its original zero without tapping. If it returns to zero only when tapped, it indicates friction in the movement and possible damage to the pivots and jewels, possible through some severe shock in transit. For portable instruments with an overall accuracy of .5 of 1% or higher, and all high torque panel types, the pointer should return to exactly zero. Ultra high sensitivity instruments in the 1% class, and thermocouple instruments in the .75 of 1% class should have a maximum deviation from zero to no more than .1 of 1% of the physical length of the scale.

The pointer should then be deflected using controlled power slowly up and down the instrument scale. The pointer action should be smooth and there should be no sticking or hesitation at any point on the scale. Do not, however, mistake a rough spot in the controls of your power supply for a "stick" in the movement. Often, a badly regulated power supply or a loose circuit connection may make the instrument appear to have an internal variable. All instrument links and leads should be carefully attached and tightened.

The new instrument should be checked against an accurate standard on the cardinal points of the scale. Just one word of CAUTION. Be careful that you do not place your new instrument and your standard too close together, especially with D.C. instruments. They may react magnetically on each other if your standard instrument is not magnetically shielded, it might indicate incorrect readings. Keep them at least six inches apart. Also, if the instrument was specially ordered for use on a steel panel (such information is printed on all our scales) then test it on a steel panel of the specified thickness.

Of all the things, that may be wrong when you get a new instrument, incorrect calibration is the LEAST likely; and if present at all, it will usually be caused by bad balance which you will already have detected by the test just covered. 99.99% of the instruments you receive, if they are satisfactory for balance, friction, stickiness etc., will also be well within their guaranteed accuracy.

NOTE:

Disassembly of the movement should not be attempted unless a skilled instrument man with calibration and scale drawing equipment are available.

CARE AND MAINTENANCE

All SENSITIVE RESEARCH instruments are individually assembled by skilled instrument makers and are INDIVIDUALLY calibrated. We do not calibrate instruments "en masse". Extreme care has been used in selecting pivots and shock mounted jewel bearings. In some instruments DIAMOND PIVOTS are used.

The instrument should be used and treated as a precision standard. A reasonable amount of care will bring its reward in a lifetime of accurate service.

Good practice dictates that periodic checks be made for pivot friction, coil, balance, scale calibration, and the mechanical integrity of any instrument.

If the instrument glass is cleaned by any method, the task should be completed by heavily breathing upon the glass so as to dissipate any electrostatic charges that may have been generated by friction. Occasionally the binding posts metal contact surfaces should be cleaned and brightened by the careful use of a fine sandpaper. A yearly coat of wax on any wooden instrument case is suggested.

Instrument panels are cleaned by using carbon tetrochloride to dissolve any greasy surface accumulations. A brisk rubbing with a soft flannel cloth will restore our moulded panels to their original lustre. Should the engraving "white" become discolored it can be removed with a sharp point and refilled with a white wax crayon material obtained from us.

OPERATIONAL PROCEDURE

1. Place the instrument on a level surface so that the scale is horizontal. Deviations of more than 5° from the horizontal may affect accuracy adversely.

2. For good instrument practice, the instrument should be kept away from any source of very strong magnetic fields. Maximum tolerable field is 5 oersted.

3. Set the pointer on zero by rotating the zero shifter, using thumb or zero screw. The pointer is correctly set on zero when the reflection of the pointer in the antiparallax mirror coincides with the pointer itself and with the zero line. (See general information sheets.) Page 4

4. For safety it is best to turn off the current or voltage to be measured before making connections to any instrument. Observing proper polarity, connect the instrument terminals in series with the circuit if current is to be measured.

   If voltage is to be measured then the voltmeter is to be in parallel to the portion of the circuit desired. It is important to remember that when an ammeter (current measuring instrument) is inserted in series with a circuit, the circuit is changed by the introduction of the ammeter resistance. Ammeters are therefore designed to be of low resistance so that they will only be a small fraction of the total resistance of a circuit.

   Remember also that when a voltmeter is connected across (in parallel) with a portion of a circuit it changes the potential difference by its own effect on the circuit and since it also is connected in parallel with a part of the circuit it reduces the effective resistance of that portion which increases in some degree the total current flowing in the complete circuit.

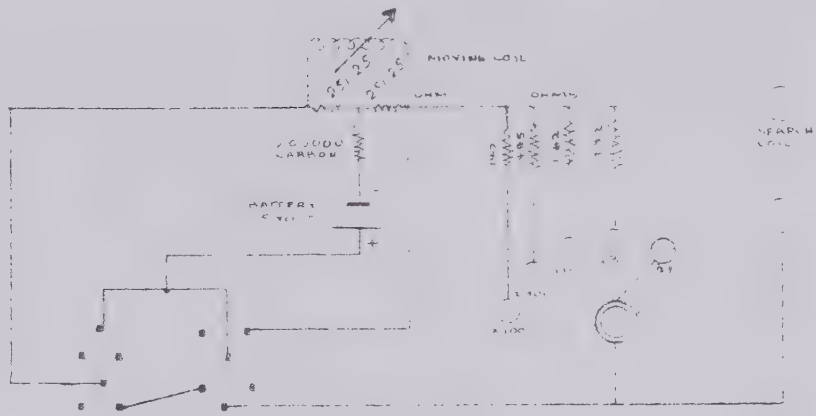
   Therefore voltmeters are designed to have the highest resistance possible so as not to change materially any circuit to which they may be applied.

5. It is considered good instrument practice in multirange instruments to have the range switch on the highest possible range and then the user can progressively switch down to the range that produces an acceptable reading. A good acceptable reading would be one in which the pointer is indicating in the upper fifth of the scale. (Nearly maximum deflection. Apply power and observe pointer deflection. When the instrument pointer has come to rest, the current is indicated by the position of the pointer on the scale.

6. After the desired measurements have completed, turn off the current supply and disconnect the instrument terminals from the source of current. If the instrument leads are left connected and circuit changes made damage could result to the instrument being on a range setting lower than the newly applied power value.

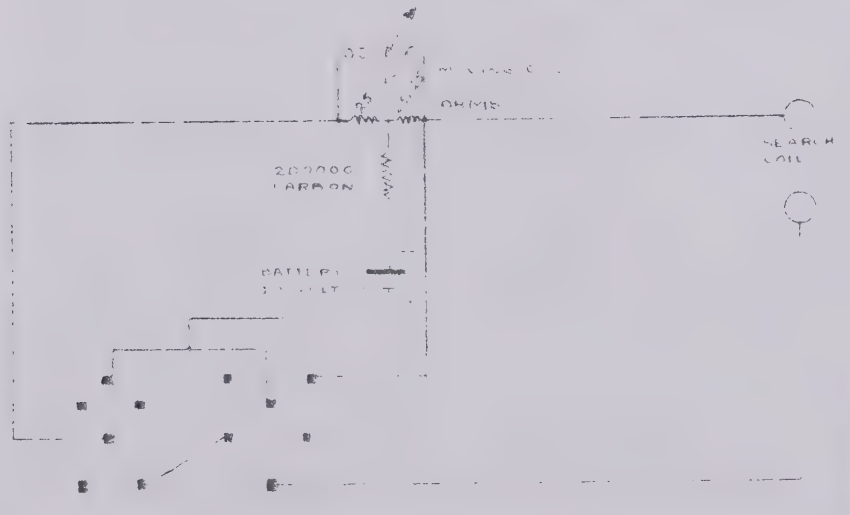
SENSITIVE RESEARCH INSTRUMENTS have a data card attached to it or mounted in its case. This data card detailing the accuracy and electrical characteristics together with the instrument panel engraving will readily enable the user to operate our instruments to their full accuracy and their personal satisfaction.

CIRCUIT DIAGRAM
FOR
MULTIRANGE FLUXMETER
LISTED IN CATALOG

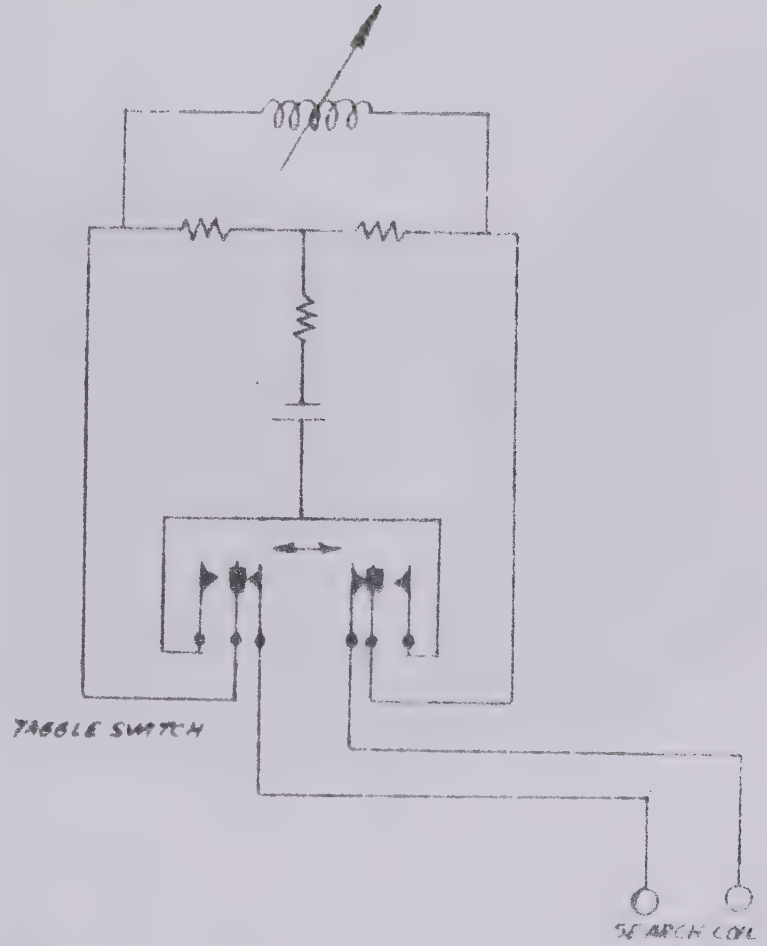


DEL. PAT. JAN 19 1926

CIRCUIT DIAGRAM
FOR
SINGLE RANGE FLUXMETER
LISTED IN CATALOG



DEL. PAT. JAN 19 1926



[redacted]

Single Range [illegible]meters

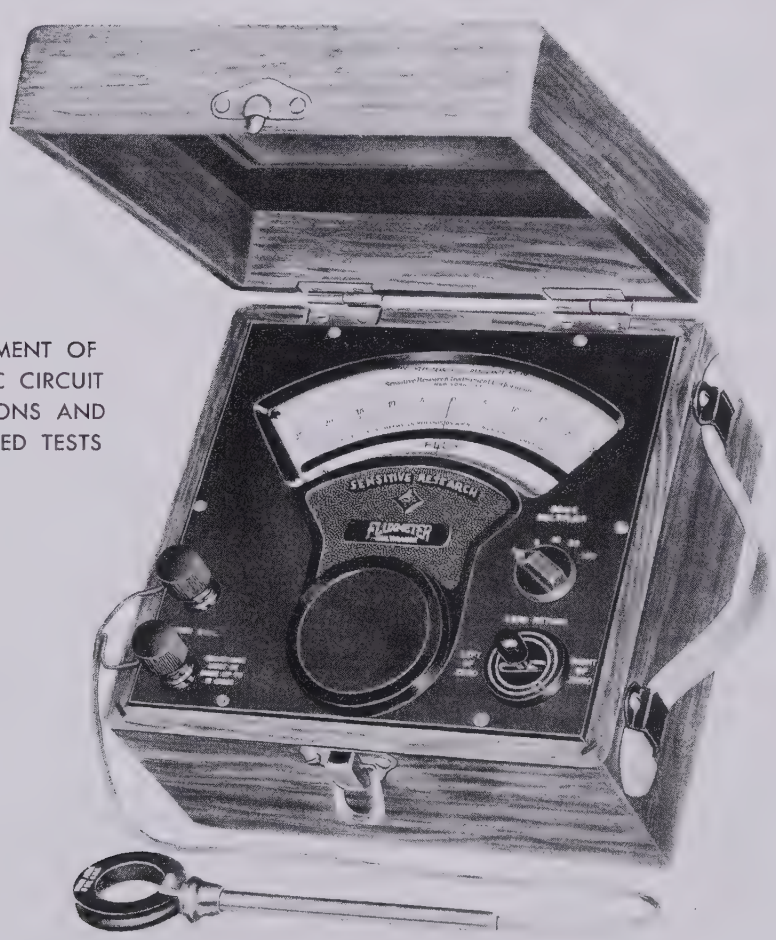
DATE 3-9-64 SCALE None

DRAWN [redacted] CHECKED [redacted]

Electrical MEASUREMENTS

VOLUME 24 SEPTEMBER 1960 NUMBER 2

D C MAGNETIC FLUX MEASUREMENTS



SEARCH COIL

FOR THE MEASUREMENT OF MAGNETIC CIRCUIT CONDITIONS AND ASSOCIATED TESTS

Our first Fluxmeter was made in June 1927

MODEL **FM**

RANGE
10 LINES PER DIVISION
(Most sensitive range)
TO
50,000,000 LINES FULL SCALE
(Highest range)

ACCURACY .5 OF 1%
SCALE LENGTH 5.2 INCHES

HAS AN
ELECTRICAL ZERO RESET

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

S
Symbol of Quality

The Model FM Fluxmeter provides a rapid, convenient and portable means of measuring magnetic flux and other investigations of magnetic fields. The instrument is entirely practical for field work as well as for laboratory measurements. Magnetic measurements may be made with the same ease that current and voltages are made on ordinary instruments by unskilled users.

SENSITIVE RESEARCH Fluxmeters measure magnetic flux in a manner somewhat similar to the ballistic galvanometer although the action is not ballistic and there is no restoring torque to make the pointer move or drift. The action of the instrument is to integrate the current flow in the search coil circuit and thereby give an indication of the energy discharged. Because of this method of measurement it is not essential that the discharge take place before the moving coil has moved appreciably as is the case with the ballistic galvanometer.

The discharge may take place over an interval of many seconds without introducing any error into the measurement. An added advantage of the SENSITIVE RESEARCH Fluxmeter over the ballistic galvanometer is that there is nominally no restoring torque in the Fluxmeter and for that reason the pointer comes to rest at the completion of the discharge. This means that the technique of reading the instrument is not at all difficult and may be mastered in a few seconds by either laboratory or production personnel.

SENSITIVE RESEARCH Fluxmeters indicate readings by means of a pointer and scale and do not require any auxiliary equipment except a search coil. They are completely portable and may be used for field, laboratory, or production measurements.

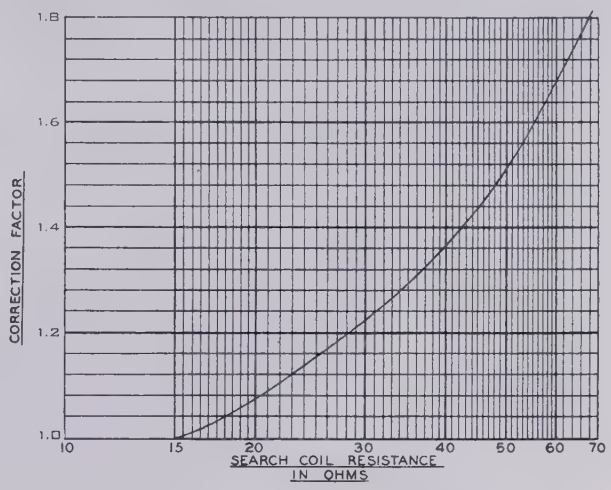
They are supplied in sensitivities from 10 lines per division to 50,000,000 lines (highest full scale value).

FLUX AND FIELD MEASUREMENTS

For the determination of total magnetic flux, flux density, or field strength, the SENSITIVE RESEARCH FLUXMETER is the most convenient means of measurement. Fundamentally the fluxmeter measures the product of the total number of flux lines cut and the number of turns in the search coil. The scale factor on the x1 range is 10,000 linkages per division. Linkages are lines times turns. Thus the total flux in Maxwells $= \frac{KD}{T}$ where K is 10,000, D is the number of divisions deflection, and T is the number of search coil turns.

It is to the user's advantage to use search coils of 10, 100, 1,000, etc. turns in order that the total flux may be read directly from the instrument scale by merely placing the decimal point properly. The scale multipliers serve to multiply "K" by the multiplier range being used.

To utilize the full accuracy of the instrument (½%) the search coil circuit must be adjusted to 15 ohms. Usually the search coil proper is less than 15 ohms and series resistance may be added. In no case should the search coil be shunted to reduce its resistance to 15 ohms. In the case of measurement of very weak fields, the search coil may have to have many turns of relatively fine wire resulting in a resistance of over 15 ohms. In this case, good comparative measurements may be made. If absolute measurements are required, the correction factors shown on the curves below should be applied to the fluxmeter readings.



Correction curve for use with search coils over 15 ohms.
Valid only for the x1 Range of the Fluxmeter.
Applies to fluxmeters manufactured after Nov. 1958.

TOTAL FLUX

Total flux measurements on permanent magnets are made by positioning the search coil in the neutral plane of the magnet, encircling the magnet itself. The instrument pointer is then brought to zero by use of the FLUXMETER ZERO CONTROL located in the lower right corner of the panel. When the search coil is withdrawn to a position out of the field of the magnet, it will have cut all of the external flux lines of the magnet. A reading is taken on the FLUXMETER scale and the deflection formula flux $= \frac{KD}{T}$ is used to determine the total flux.

The total flux of electro-magnets may be measured the same as permanent magnets, with the electro-magnet energized. An alternative method for electro-magnets is to first demagnetize the magnetic core to eliminate the residual flux. A search coil is then placed in a position to encircle the flux to be measured. After setting the FLUXMETER pointer to zero by the use of the FLUXMETER ZERO CONTROL, the electro-magnet is energized and a reading taken on the FLUXMETER. The deflection formula is then used to obtain the total flux.

$$\text{Total Flux} = \frac{KD}{T} \text{ (Maxwells) C. G. S. lines}$$

K = 10,000 maxwells per division
D = divisions deflection
T = number turns in search coil
(In this case that of the x1 Range)

FIELD MEASUREMENTS

The strength of a magnetic field may be measured with the FLUXMETER by using the relationship that the field strength is equal to total flux in a given cross sectional area divided by that area. The cross sectional area must be perpendicular to the direction of the field. Field measurements are made by measuring flux with a search coil of known area. The units of field intensity are gausses in the c.g.s. system and lines per square inch in the English mixed system. The Maxwell and the line are all the same quantity. (1 gauss = 1 Maxwell per square centimeter).

One technique for measuring a field is to align the axis of the search coil winding with the direction of the field and set the FLUXMETER pointer to zero by use of the FLUXMETER ZERO CONTROL located in the lower right corner of the panel. The search coil is then rotated 180° so that its axis is again aligned with the field and a reading taken on the FLUXMETER. The search coil has then cut the enclosed flux twice. The flux density is then computed from the deflection formula: Flux Density $= \frac{KDR}{2TA}$ where K is 10,000, D is the pointer deflection in divisions, R is the multiplier range used, T is the number of turns in the search coil and A is the mean area of the search coil in appropriate units for the system being used.

Another technique for making flux density measurements is usable if the search coil may be moved to an area of negligible flux density. The search coil is placed in the field to be measured. The FLUXMETER pointer is then set on zero, the search coil removed from the field, and a reading taken on the FLUXMETER. The flux density is then computed from the formula:

$$\text{Flux Density} = \frac{KDR}{TA}$$

HYSTERESIS LOOPS

The determination of the hysteresis loop of a magnetic specimen requires that the specimen first be in the steady state cyclic condition. This condition exists when the specimen has been subjected alternately to a positive and negative magnetizing force through at least 10 complete cycles. The material then behaves as shown by the arrows in Fig. 2.

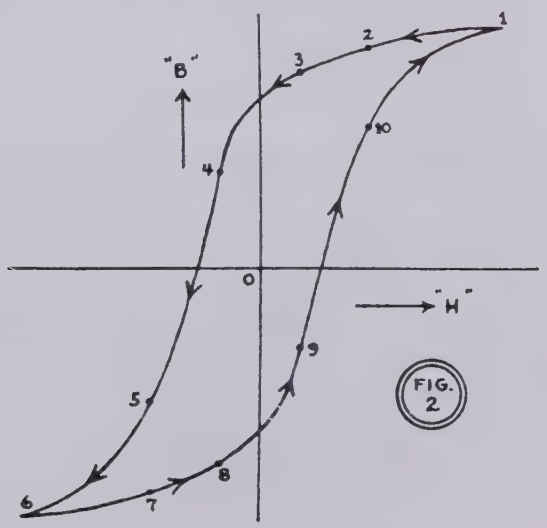
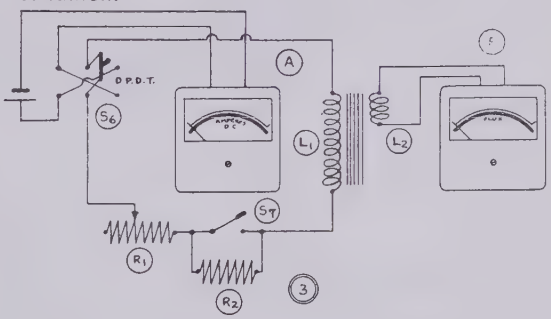


FIG. 2

The points 1 and 6 are determined only if the material is in the cyclic condition and Hmax and – Hmax are constant. Furthermore, any point on the curve may be determined **only** if it is approached under the requirements of the cyclic condition. For example, if the point 2 is to be found, it must be approached **FROM** the point 1. The establishment of any condition which causes the history of the material to be other than shown, as for example approaching any point except 1 or 6 and reversing the direction of the magnetizing force, will place the material in some condition other than the desired cyclic condition.



The circuit shown in Fig. 3 enables the necessary measurements to be made for the determination of the hysteresis loop. The resistance R1 is used for adjusting the current in the magnetizing winding L1. Switch S6 is provided for reversing the direction of the magnetizing force in the specimen by reversing the current without changing the magnitude. This enables the cyclic condition to be established. The current may be reduced by opening switch S7 after having previously adjusted resistance R2 to obtain the desired current. Thus the magnetizing force may be conveniently reduced from ± Hmax to some value of smaller magnitude without disturbing the cyclic condition of the specimen. The fluxmeter (F) is used to measure the changes of flux enclosed by the search coil L2.

The magnetizing field is easily determined from the CURRENT in and the pitch of the magnetizing winding. Long thin samples can also be used in which the free poles will have little effect.

Magnetizing force in Oersteds (Gilberts per CM.) $= H = \frac{.4\pi NI}{L}$

N = Number of turns in Primary Winding

I = Primary current in Amperes

L = Mean Length of Magnetic Path in CM. $= 2\pi r$ where r is mean radius of ring in CM.

Flux Density in Maxwells per square CM. or GAUSSES $= B = \frac{DK}{2A^1NS}$

Ns = Number of turns in secondary winding

D = Fluxmeter deflection

K = Maxwells per division of fluxmeter

A^1 = Cross Sectional area of magnetic path in sq. cm.

2 = Constant because current is reversed and flux density changes from + B to — B

(3) PERMEABILITY

This is obtained by using data obtained from (2).

$$\text{Permeability} = \frac{B}{H} = \frac{\text{Gausses}}{\text{Oersteds (Gilberts per CM.)}}$$

HYSTERESIS LOOPS OF SMALL CORE OR RING SPECIMENS

The determination of the hysteresis loop of a specimen of magnetic material requires that known values of H, the magnetizing force, be applied to the specimen and the corresponding values of B, the flux density, be measured. The restrictions as to cyclic condition, etc. as mentioned before, must be observed if valid measurements are to be made.

The procedure for determining points on the hysteresis loop is to establish the current corresponding to ± Hmax (see Fig. 2) with switch S7 closed. The D.C. Ammeter is used for measuring the current. The current required will be $I = \frac{H1}{.4\pi N}$ where I is current in amperes, H is the desired magnetizing force in oersteds, 1 is the *EFFECTIVE length of the magnetic path, and N is the number of turns in the magnetizing winding. Then with switch S7 open, the value of H is adjusted to a lower value corresponding for instance to points 2 and 10, and 5 and 7 when H is reversed. These preliminary adjustments prepare the equipment for the determination of points 1, 2, 5, 6, 7, and 10 on Fig. 2.

Almost any size and shape of specimen may be used to determine the hysteresis loop of a material, provided that its effective magnetic length and cross section can be determined. Many times engineers need a method for testing a transformer core with windings already assembled. In general, the low impedance type of winding is suitable for use as a magnetizing winding or an exploring winding for connection to the fluxmeter. The value of B, the flux density, can be calculated by dividing the total flux Ø [or the change in flux (Øn-Øm)] by the cross sectional area of the core where the exploring winding is wound.

The fluxmeter measures change of total flux linkages from one condition to another. The number of flux linkages is the product of flux lines or Maxwells and the number of turns in the exploring coil. The total flux measured then, is

$$\text{Maxwells} = \frac{\text{Divisions Deflection x } 10{,}000}{\text{Search Coil Turns}}$$

It is important to note that the fluxmeter search coil circuit resistance must be 15 ohms. Usually the exploring winding is less than 15 ohms and series resistance is added to bring the circuit to the required value. The search coil should not be shunted to reduce its resistance.

The specimen to be measured may be a core with appropriate windings already assembled or it may be a core upon which windings may be placed. The relationship of $H = \frac{.4\pi NI}{l}$ is a guide as to the number of turns required for the desired value of H (in oersteds).

A reversing switch is used as S6 and a single pole switch is to be used as S7.

*M.I.T. "Magnetic Circuits & Transformers"—E. E. STAFF

With S7 closed, the current is reversed 15 or 20 times to obtain the cyclic condition. The reversing should be stopped with S6 in the position to give – Hmax. Before each of the following switch operations, the fluxmeter should be set to zero by means of the zero control provided. The following procedure will determine the points 1, 2, 5, 6, 7, and 10.

1st Switch from —Hmax to +Hmax using switch S6. This will give a reading of 2ømax on the fluxmeter which can be converted to Bmax by dividing by two (2) times the cross sectional area of A. $B_1 = \frac{2\ \text{ø max}}{2A} = \frac{\text{fluxmeter reading}}{2A}$

2nd Open Sw7 which sets the current for H2. The fluxmeter will read ømax — ø2. $B_2 = B_1 - \frac{\text{Fluxmeter Reading}}{A}$

3rd Reverse switch S6 which will establish H5 and the fluxmeter will then read ø2 — ø5. $B_5 = B_2 - \frac{\text{Fluxmeter Reading}}{A}$

4th Close switch S7 which will then establish H6 and the fluxmeter reading will be ø6 — ø5. $B_6 = B_5 - \frac{\text{Fluxmeter Reading}}{A}$

5th Open switch S7 to establish H7. Fluxmeter will read ø7 — ø6. $B_7 = B_6 - \frac{\text{Fluxmeter Reading}}{A}$

6th Reverse switch S6 to establish H10. Fluxmeter will read ø7 + ø10. $B_{10} = B_7 - \frac{\text{Fluxmeter Reading}}{A}$

The polarity of Fluxmeter Readings must be checked for inclusion in the above formulas.

Using the values of H and ø (or B) from above the points 1, 2, 5, 6, 7, and 10 may be plotted. A similar procedure can be used to determine another set of points such as 1, 3, 4, 6, 8, 9. As many points as are required for the particular problem may be determined by selecting appropriate values of H. It is very important to observe all necessary precautions to insure that the measurements are made with the material in the cyclic condition as shown by the arrow heads in Fig. 2. (See page 3)

DESIGN OF SEARCH COILS TOTAL FLUX MEASUREMENTS

In the measurement of total flux, the area of the search coil is of minor importance. The deflection formula for the Fluxmeter may be rearranged to the following form: $T = \frac{KD}{Ø}$ where T is the number of turns in the search coil, K is the instrument constant of lines per division, D is the desired deflection in divisions, and Ø is the total flux to be measured. This formula makes possible the computation of the required number of turns. Care should be taken to make the search coil a suitable size so that it can be manipulated easily and so that it is not so large as to enclose extraneous fields.

FLUX DENSITY MEASUREMENTS

In the measurement of flux density, the mean effective area of the search coil must be *accurately known.

*In the measurement of flux density in soft magnetic core material, the cross sectional area of the core should be used since it is assumed that all except a negligible portion of the flux exists in the core material itself.

The Fluxmeter deflection depends upon total flux change and number of search coil turns. The total flux change will be the product of the flux density (B) in gausses and the mean area (A) in square centimeters of the search coil. The Fluxmeter deflection formula may then be written $T = \frac{KD}{BA}$. Frequently the design of a search coil is limited by the maximum allowable size or area of the search coil. When maximum size is the limiting factor, the maximum area should first be computed and then the required number of turns may be calculated from the deflection formula. In calculating the effective area of the search coil, the mean diameter of the search coil must be used. This dimension is shown as "X" in Figure below and if X in centimeters the area in square centimeters $= \frac{3.1416X^2}{4}$

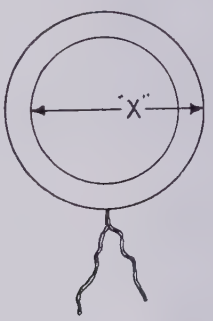
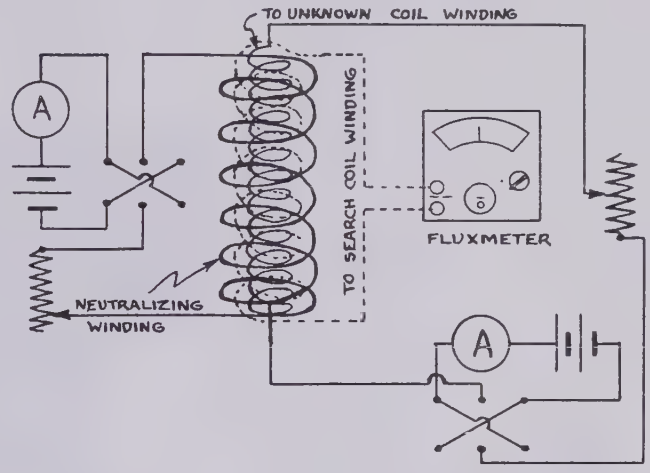


Figure No. 1
(Twist leads to Fluxmeter)

If possible, the wire size used in the search coils should be chosen so that the winding resistance is 15 ohms or less. When the search coil is wound, its resistance should be measured and sufficient resistance should be added in series to give a total resistance of 15 ohms. Sometimes the required winding will have to measure more than 15 ohms in order to gain sufficient sensitivity. If this is the case then a correction factor may be taken from the curve shown on page 2.

The curves of correction factors vs. search coil resistance are valid ONLY for the basic range of the Fluxmeter and may not be used for the multiplier ranges.

DETERMINING THE NUMBER OF TURNS IN AN UNKNOWN COIL THAT IS WOUND ON AN IRON CORE OR CAN BE PLACED ON AN IRON CORE



This can easily be done without destroying the coil in order to count the turns. Wind a few turns distributed along the length of the unknown coil and connect to the Fluxmeter. Reverse a measured current through the unknown coil and note the deflection on the Fluxmeter. Wind a counted number of turns over both the unknown coil and search coil and reverse a current through this coil just sufficient to produce the same Fluxmeter deflection. At that point the ampere turns of the unknown coil and the second coil are equal and the number of turns in the unknown are easily determined.

$$\text{Unknown Turns} = \frac{\text{Ampere turns in neutralizing winding}}{\text{Amperes in unknown winding}}$$

If the coil to be checked is NOT on a core of ferro-magnetic material, it may be placed temporarily on some form of a closed magnetic path.

ULTRA SENSITIVE DETECTOR OR D.C. BRIDGE CIRCUITS

The fluxmeter can be used as a very low resistance, high sensitivity null detector for use in any circuit requiring such a detector. Low resistance bridge circuits and low millivolt balance potential circuits are particularly in need of such a detector. The fluxmeter with an internal resistance of only 25 ohms will readily detect currents of 1 microampere. Balance is achieved when the fluxmeter does not move, regardless of where the pointer may rest. Unbalance is indicated by speed of movement and direction of movement indicates direction of unbalance.

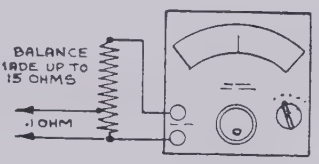
MEASUREMENT OF ELECTRICAL DISCHARGES

In this case the Fluxmeter can be considered a calibrated coulomb meter. The discharge must take place through a low resistance, non inductive shunt having a resistance of not over .1 ohm. Connect the Fluxmeter as shown. Under the above conditions:—

$$\text{Coulombs discharged} = (Q) = \frac{DK}{R \times 10^8}$$

D = Fluxmeter deflection
K = Maxwells per division of Fluxmeter
R = Resistance of Shunt in ohms

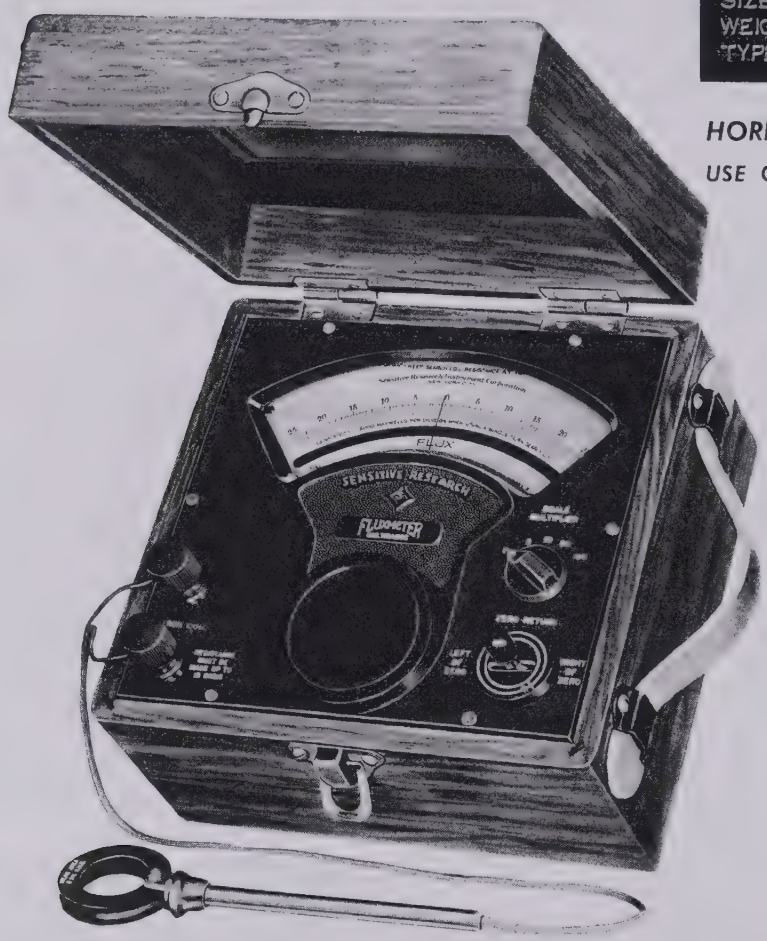
$$\text{Milliampere seconds discharged} = \frac{DK}{R \times 10^5}$$



MODEL FM

ACCURACY	.5 of 1% - x1, x3 ranges 1% - x10, x30, x100 ranges
SCALE	5.2"
PERIOD	Ballistic
SIZE	8"x7½"x6"
WEIGHT	6 lbs.
TYPE	D'Arsonval Double Pivot

HORIZONTAL
USE ONLY



Measures DC Magnetic Flux Density and DC Magnetic Field Strength. For use in place of a Ballistic Galvanometer, and in applications requiring general DC Magnetic Testing and Integration.

Standard Scale
Printed 50 - 0 - 50

Furnished in a
FORMICA CASE

Such cases, we believe, are the finest in "the state of the art." They are structurally strong, dimensionally stable, and extremely resistant to deterioration from rough handling or adverse environmental conditions. In addition, they are furnished with a fitted panel gasket, which serves as an effective dust seal. The formica case itself is a good humidity BARRIER. The finish of any formica case will be like "new" even though subjected to the severest usage.

Each Fluxmeter is supplied with an internally mounted mercury cell to actuate the zero return winding. The current drain on this cell is so low that the cell lasts as long as it would on a shelf. However, when replacement becomes necessary, a small, easily procured flashlight cell can be replaced by the user most readily from the bottom of the case.

We regret that we cannot build special search coils to order.

	5 Switch Controlled Ranges	Code	Price
MULTIRANGE FLUXMETER		FLUXO	$310.00

Ranges x1, x3, x10, x30, x100. (Basic sensitivity on x1 range 10,000 lines per division using a 1 turn search coil.)

We suggest the purchase of a general purpose search coil having a mean area of 15 square centimeters and 10 turns (see picture of FLUXMETER). This has a hole through its center of 1½" and is mounted in a handle 5" long with 3 foot test leads, resistance exactly 15 ohms.

GENERAL PURPOSE SEARCH COIL — Price $40.00

Standard "U" shaped magnet with total open circuit flux measured within an accuracy of 1%. Any value available from 10,000 to 50,000 lines as desired. If value is not specified, a 25,000 line magnet will be supplied. Price $40.00

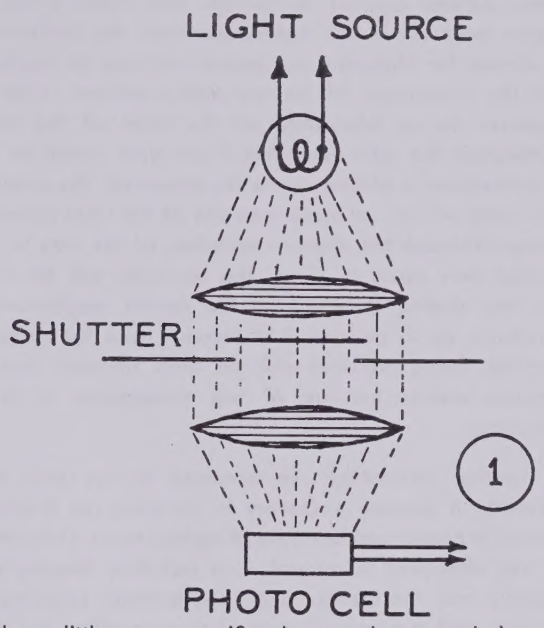
Special combination magnet and search coil for the calibration of fluxmeters -- for a 25,000 line deflection to an accuracy of .5 of 1%. Price $85.00

THAT VERSATILE FLUXMETER

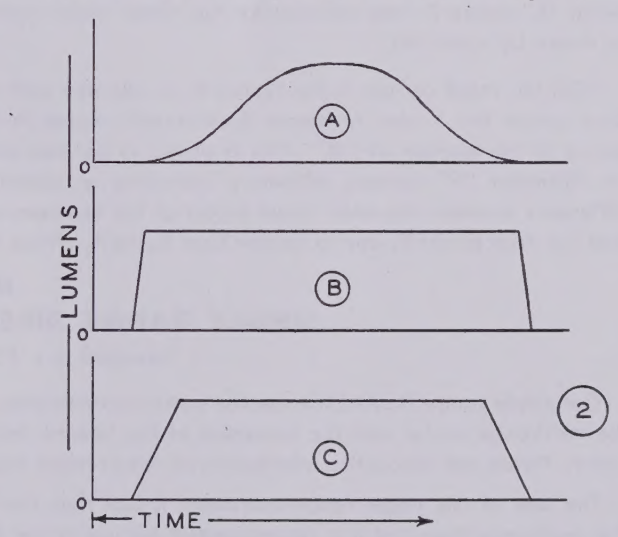
Sensitive Research Instrument Corporation has been building fluxmeters since 1927. During the years from then until the present these instruments have been sold primarily as an instrument for the measurement of flux densities. As a flux measuring design, it has had widespread use and has earned itself a well deserved reputation as an accurate dependable instrument.

The FLUXMETER is, however, perfectly capable of leading a double life. Or, for that matter, a triple or quadruple existence. We have in past issues of *Electrical Measurements* discussed instruments that could add, subtract, multiply, and divide. On that basis of direct arithmetic ability the FLUXMETER puts other instruments to shame. The fluxmeter leaves grade school arithmetic behind and steps into higher mathematics. The fluxmeter can integrate accurately within quite wide limits. This is an attribute that has been little exploited in this type of instrument. In any operation in the expression $X = \int_{T_1}^{T_2} Y$, and Y is either a current or voltage, or can be changed to an electrical current or voltage, the fluxmeter can evaluate the integral and indicate the value of X on its scale.

Of course, like everything else in instrumentation there have to be certain limitations imposed for complete accuracy. The electrical quantity representing Y must not contain components with effective frequencies so high that the distributed capacity of the moving coil becomes an appreciable shunt. The time between T_1 and T_2 must not be so long that the instrument drift is appreciable. In the standard instrument this means that for 1% accuracy the current representing Y must not have components with effective frequencies higher than 25 kilocycles and that the total time is not more than 5 seconds. For 5% these limitations change to about 50 kilocycles and 10 seconds. This gives a very wide range of operation over which the fluxmeter is an accurate integrating device.



To be a little more specific about such usage, let's go into a few examples. Assume that we have a requirement for direct measurement of the amount of light transmitted by three different types of light shutters. When set up, the output of a photocell gave very satisfactorily the instantaneous value of the light transmitted. However, the three different types of shutters gave curves with time versus light output as shown in fig. (B).

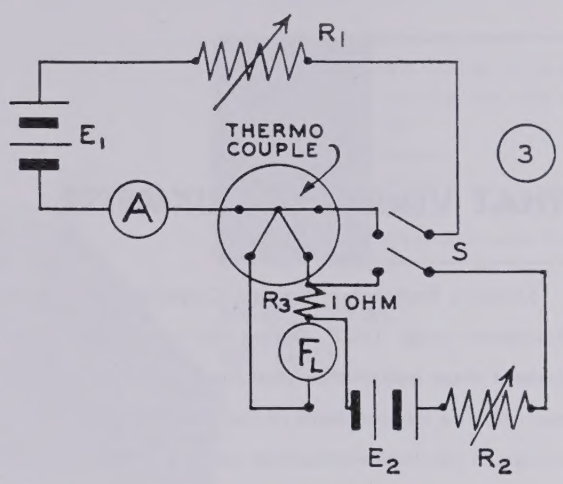


Curve "A' is for an iris type shutter which opens very gradually and closes the same way. For many cases this type of shutter barely reaches a completely open position when it starts to reclose and a great portion of the total light passed is during the partially open positions. Curve "B" is for the focal plane shutter where an open slit moves across the shutter area. In the case where the slit width is small, the output has a very abrupt opening and closing and the light output is somewhat intermediate between the other two types. As soon as one tries to devise a fool proof comparison of the 3 shutters on the basis of the total light delivered, difficulties are encountered.

The photocell can be used as a trigger to open a relay at some defined level of illumination and measure time that the beam stays above this illumination level. No matter what level is chosen for triggering the answer can only be made accurate for the comparison of the two *similar* shutters. What is really required is an integration of the level of the illumination throughout the total time. This is just what would be indicated if a fluxmeter is placed across the photocell. The reading of the fluxmeter will be an exact measure of the total quanta of light passed through the shutter regardless of the way in which the shutter may open or close. The accuracy will be maintained for any shutter speeds from the fastest mechanical shutters available up to periods of 5 seconds, and for longer periods regular timing methods can be used because opening and closure speeds become of less importance in the overall accuracy.

Another interesting use occurred in our own laboratory recently. It became necessary to compare the thermal energy stored in heater and junctions of various types of thermocouples. It was attempted in several ways including feeding sine wave signals into the heater and progressively reducing the frequency until the junction output began to follow the cyclic heat sufficiently to show variations during the cycle. This posed problems of providing slow sine waves of fractional cycles and of measuring the output variations with sufficient accuracy to attain reasonable comparison of the thermal capacities of the various couples. The circuit of fig. (3) was finally used. With switch "S" closed R_1 was adjusted for the rated heater current as shown by meter (A).

With this rated current in the heater, R_2 is adjusted until the drop across the 1 ohm resistance R_3 is exactly equal to the output of the junction of "TC". This is shown to be true when the fluxmeter "F" remains *stationary* indicating no potential difference between the open circuit output of the thermocouple and the drop across R_3 due to current from E_2 via R_2. When this



condition is established the fluxmeter is zeroed by its own internal circuit. If switch "S" is now opened the heater current is stopped and the heater of "TC" begins to cool and soon reaches room temperature. Switch "S" also simultaneously opened the circuit from E_2 to the fluxmeter leaving it connected only to the junction and hence indicating by the current flowing through it the instantaneous temperature of the junction. The junction gives output proportional to the temperature of the couple as it cools and finally reaches ambient. The fluxmeter moves with a speed proportional to that output and eventually comes to rest as the heater temperature reaches ambient, having integrated the total millivolt seconds during this period. Hence its reading when it comes to rest is proportional to the thermal energy stored in the heater at the time of current interruption. This test set up allowed the evaluation of this factor in many couples in a very short time.

The above descriptions are only intended to be indicative of what can be done by such a simple and satisfactory integrating device. It is hoped that it may spark a thought that will help solve some of your problems.

MODEL FS
SINGLE RANGE DIRECT READING D C FLUXMETER

Furnished in a FORMICA CASE (See page 6)

Our single range FLUXMETER has the same characteristics as the multirange model with the exception of the internal range switch. Please see descriptive information on the previous page.

The cost of this single range instrument is less than that of the multirange type and it is recommended for use in low flux measurements. Its normal sensitivity is 10,000 maxwells per division using a **ONE TURN** search coil.

Scale is zero center *50 — 0 — 50* *(100 divisions)*

Using a search coil with additional turns, this sensitivity is materially increased:

A 1,000 turn search coil = 10 maxwells per division
A 100 turn search coil = 100 maxwells per division
A 10 turn search coil = 1,000 maxwells per division
A 1 turn search coil = 10,000 maxwells per division

The resistance of the search coil when used with the single range fluxmeter must be made up to 15 ohms to insure proper accuracy.

Full Scale Range (Maxwells) With One Turn Search Coil	Accuracy	Maxwells Per Division With One Turn Search Coil	Code Word	Price
500,000 (Described above)	.5%	10,000	FLUXA	$215.00
1,500,000	.5%	30,000	FLUXE	215.00
5,000,000	1%	100,000	FLUXI	215.00
15,000,000	1%	300,000	FLUXU	215.00
50,000,000	1%	1,000,000	FLUXY	215.00

Our general purpose search coil and calibrating magnet and its search coil are available for use with this model FS (Please see page 6)

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Prices and specifications subject to change without notice.

MP MASTER
MA34381